Space Weather Technical Forecast

Issued on Tuesday, 28 November 2023 at 13:22 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: M-flares likely (R1-R2 Blackouts). Chance of G1 Minor Storms day 3-4 (30 Nov-01 Dec) due to CME arrivals

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Low, with a peak flare C6.7 at 27/1852 UTC, from a combined filament eruption from the northeast disc and flare from AR3500 in the southeast quadrant. This is the most notable and largest of the eleven visible sunspot regions and is comprised of a compact cluster of dark umbra, most with penumbra. Some recent flux emergence near the trailer region has also led to a more complex magnetic structure developing. All other regions on the disc remain smaller and simpler, and either stable or showing signs of decay.

There are also a number of filaments on the Earth-facing disc. Two of these erupted to produce CMEs, the first alongside the C6.7 at 27/1852 UTC, and the second with a C5.6 flare peaking at 27/2340 UTC. The first produced a weak and slow, but partial halo CME, while the second produce a faster CME that was more off the Earth-Sun line. However both of these have been assessed as having potential Earth-directed components arriving on day 3 and 4 (30 Nov and 01 Dec).

Solar Wind / Geomagnetic Activity: Solar wind speeds have been at slightly elevated winds speeds, around 450-500 km/s. Density has been around average. Interplanetary Magnetic Field (IMF), Bt, was weak varying between 4-6nT, with the north-south component, Bz also varying weakly. Phi angle was mainly positive (away from the Sun). Geomagnetic activity was Quiet to Unsettled.

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux remained at background. GOES16 high energy (greater than 2MeV) electron flux has been at Background. The associated 24-hour fluence has remained below the Active threshold (1e8 integrated pfu). The observation at 28/0000 UTC was 2.4e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Low to Moderate with the likelihood of isolated M-flares (R1-R2 Blackout). These most likely from AR3500, which also brings a slight chance of an isolated X-class flare (R3 Blackout).

Solar Wind / Geomagnetic Activity: There are three CMEs that may impact Earth. The first from a filament eruption on 27 Nov is forecast to arrive early on day 3 (30 Nov) giving a glancing impact. The CME from the 27/2340 UTC filament eruption is forecast to largely miss, but with the potential for glancing impacts later on day 3 (30 Nov), however this may also combine with the earlier arrival to give a stronger impact. The third arrival has higher confidence for impact Earth, but is slower and weaker, likely arriving late on day 4 (01 Dec). Aside from the CMEs, current slightly elevated solar wind, perhaps due to ongoing influence of CH75, is expected to soon ease to background day 1-2 (28-29 Nov). Mainly Quiet geomagnetic activity is forecast with a chance of isolated Unsettled spells. Any CME arrivals are likely to bring a spell of Active to G1-Minor Storms, with a slight chance of G2 Moderate Storm intervals. These most likely if a combined arrival occurs day 3 (30 Nov).

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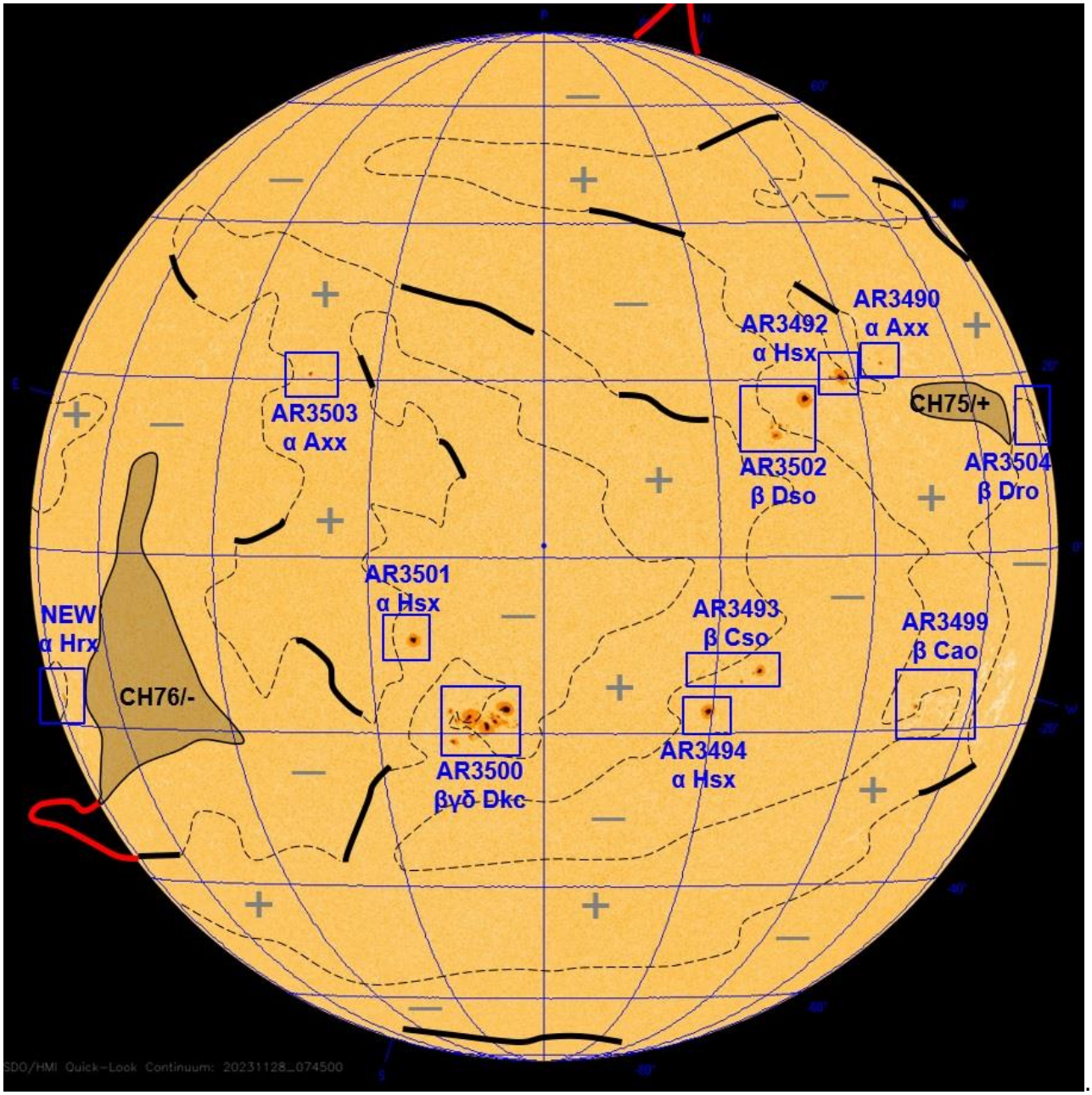
Energetic Particles / Solar Radiation: GOES16 high energy proton flux is expected to remain at background levels. There is a slight chance of flux towards or perhaps exceeding the S1 level given any significant flares from the active regions on the disc, or from any notable filament eruptions. Electron flux is currently at background, but perhaps trending towards moderate or high on diurnal peaks through days 1-2 (28-29 Nov). Any increase is likely to be suppressed again by the possible CME arrivals. The associated fluence is expected to increase in response, but likely staying below the Active (1e8 integrated pfu) threshold.

Figure 1. Solar Analysis Valid 28/0800 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

There are up to three Earth-directed CMEs.
Two glancing impacts are possible on 01 Dec. The first was due to a filament eruption from the southwest disc around 27/0535 UTC off the southwest disc. This has been reanalysed and is forecast to give a glancing impact on day 3 at 30/0700 UTC, with the bulk of the material will passing south of earth. The second is due to a large filament eruption off the northeast disc 27/2340 UTC. This is a faster CME, that is expected to largely miss behind and north of Earth, however there is a potential for a glancing impact either later on day 3 (30 Nov), or perhaps combining to enhance the first arrival.
The third is due to a filament eruption from the northeast disc around 27/1840 UTC, coincident with a C6.7 flare from AR3500 in the southeast. A subsequent faint partial halo CME was observed heading southeast. This is more likely to impact Earth than the above eruptions, however this is a slower CME, and not expected to arrive until day 4, around 01/1800 UTC.
Aside from the CMEs solar winds are expected to ease to background later day 1 and day 2 (28-29 Nov) as the influence of coronal hole 75 recedes. No further coronal hole source enhancements are expected.
Mainly Quiet geomagnetic activity is forecast with a chance of isolated Unsettled spells. Any CME arrivals are likely to bring a spell of Active to G1-Minor Storms, with a slight chance of G2 Moderate Storm intervals. These most likely if a combined arrival occurs day 3 (30 Nov).

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	1	10	40	30
Strong	G3	No	1	2	5	5
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
27/1235	Nil	Filament	SW	575 km/s	Early 30 Nov	Glancing impact
28/0302	Partial	Filament	NE	1040 km/s	Late 30 Nov	Glancing impact. Low confidence.
28/0800	Partial	Filament and C6.7 AR3500	NE/SE	380 km/s	Late 01 Dec	Minimal impact expected

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Figure 2: SOHO C2 imagery showing each CME (in table order) with arrows showing direction of CME

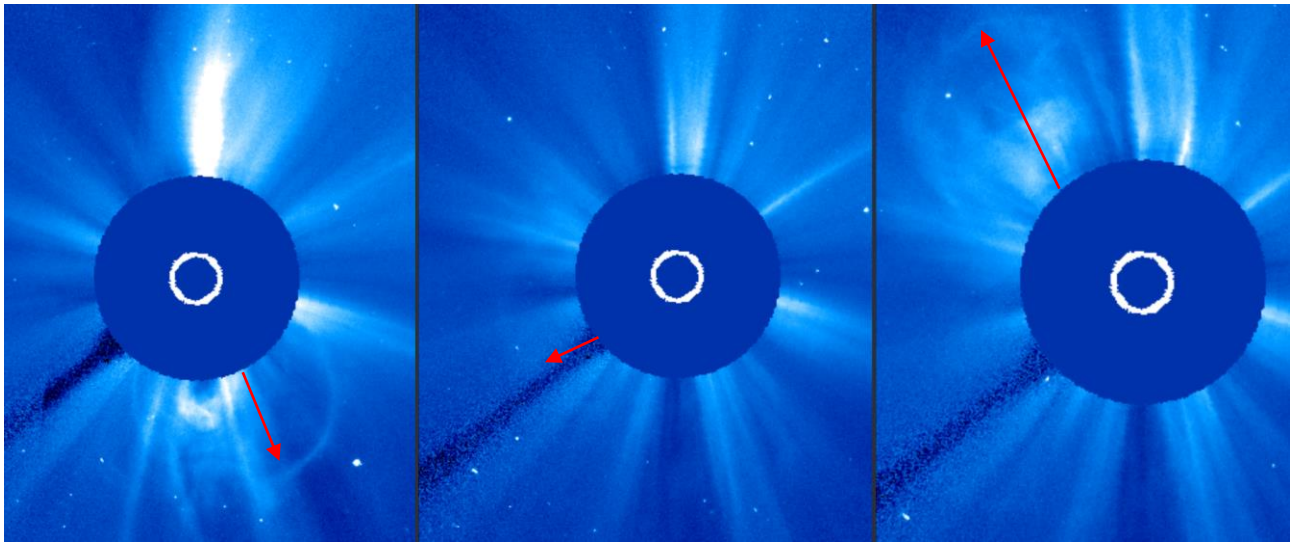
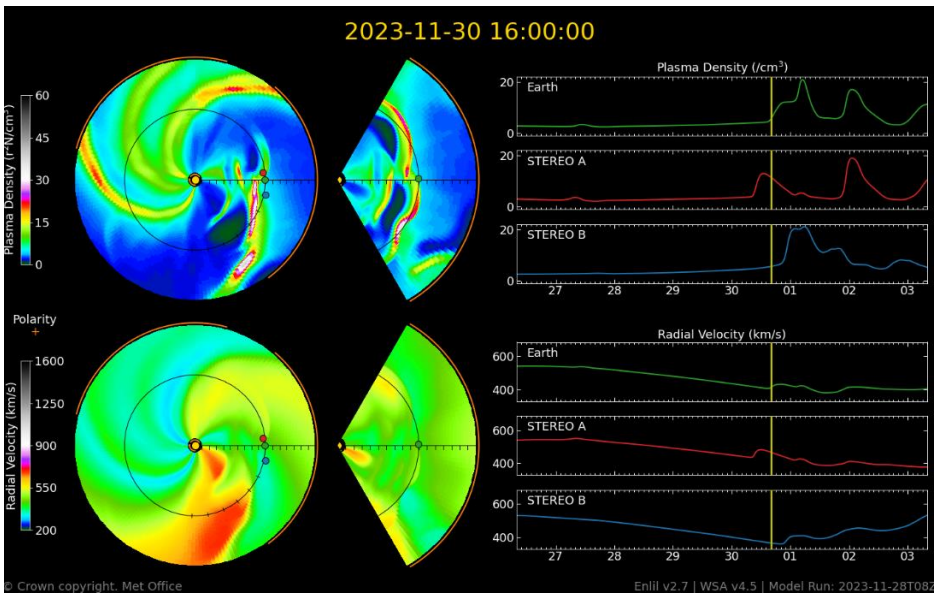
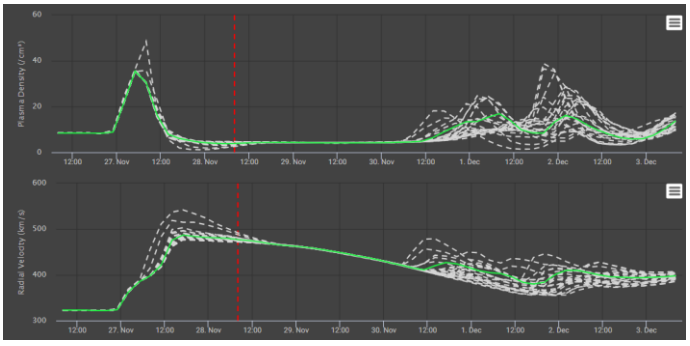


Figure 3: Enlil and ensemble currently showing arrival of first CME, with following CMEs visible.





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Radio Blackouts - X-Ray Flares:

Low to Moderate activity is forecast, with a likelihood of isolated M-flares.

There are eleven sunspot regions on the Earth-facing disc, however most of these are simple and either stable or in decline. The main exception is the moderately sized region AR3500 in the south centre disc. This is formed from a compact cluster of dark umbrae with surrounding penumbra, and recent flux emergence has resulted in a complex magnetic structure (beta-gamma-delta) developing. Ongoing growth of this region is possible, bringing a slight chance of X-class flares.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	No	60	60	60	60
Very Active	R3 to R5 X Class	No	10	10	10	10

Figure 3: GOES-16/18 X-ray Flux

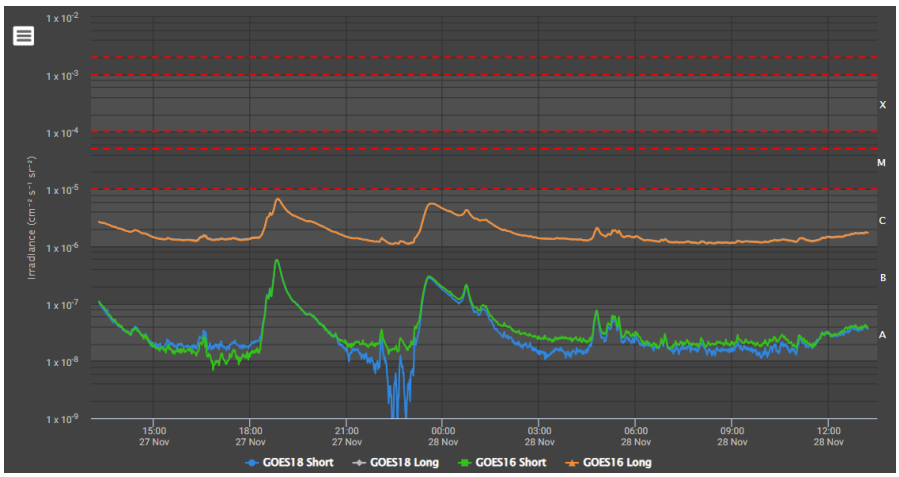
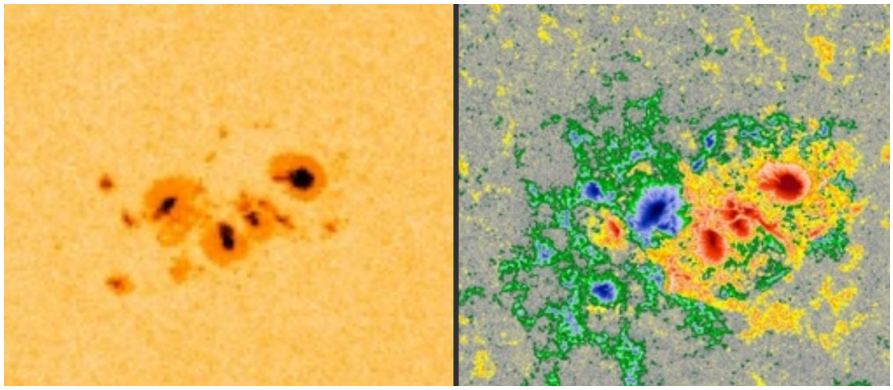


Figure 3: SDO hmi intensitygram (left) and magnetogram (right) of AR3500



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Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux observed by GOES16 is currently at background. There are number of moderately sized sunspot regions on the disc, however the majority of these are magnetically simple mature spots with no significant activity. The main region of note is currently AR3500 in the southeast, which is both the largest region and maintains a weakening beta-delta configuration. There are also a number of filaments on the Earth-facing disc, and large eruptions, especially off the west disc, can result in proton flux increasing at Earth, albeit likely staying below the S1 Minor Radiation Storm level.

Overall this gives a slight chance of elevated protons through the period, with this risk increasing a little as AR3500 moves into the western disc.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	5	10	10	10
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) as observed by GOES-16 is currently at background in the presence of a slightly elevated solar wind. As the solar wind speed eases through day 1 (28 Nov) a slight increase in electron flux values is possible, likely rising to moderate levels and potentially to high levels on diurnal peaks. However any increases are subject to the possible CME arrivals on day 3 or 4 (30 Nov or 01 Dec), which are likely to further suppress values.

Overall electron fluence is expected to remain below the Active threshold (1e8 integrated pfu), but with an upward trend possible through until later on 29 Nov. This is supported by REFM.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	1	1	5
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

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